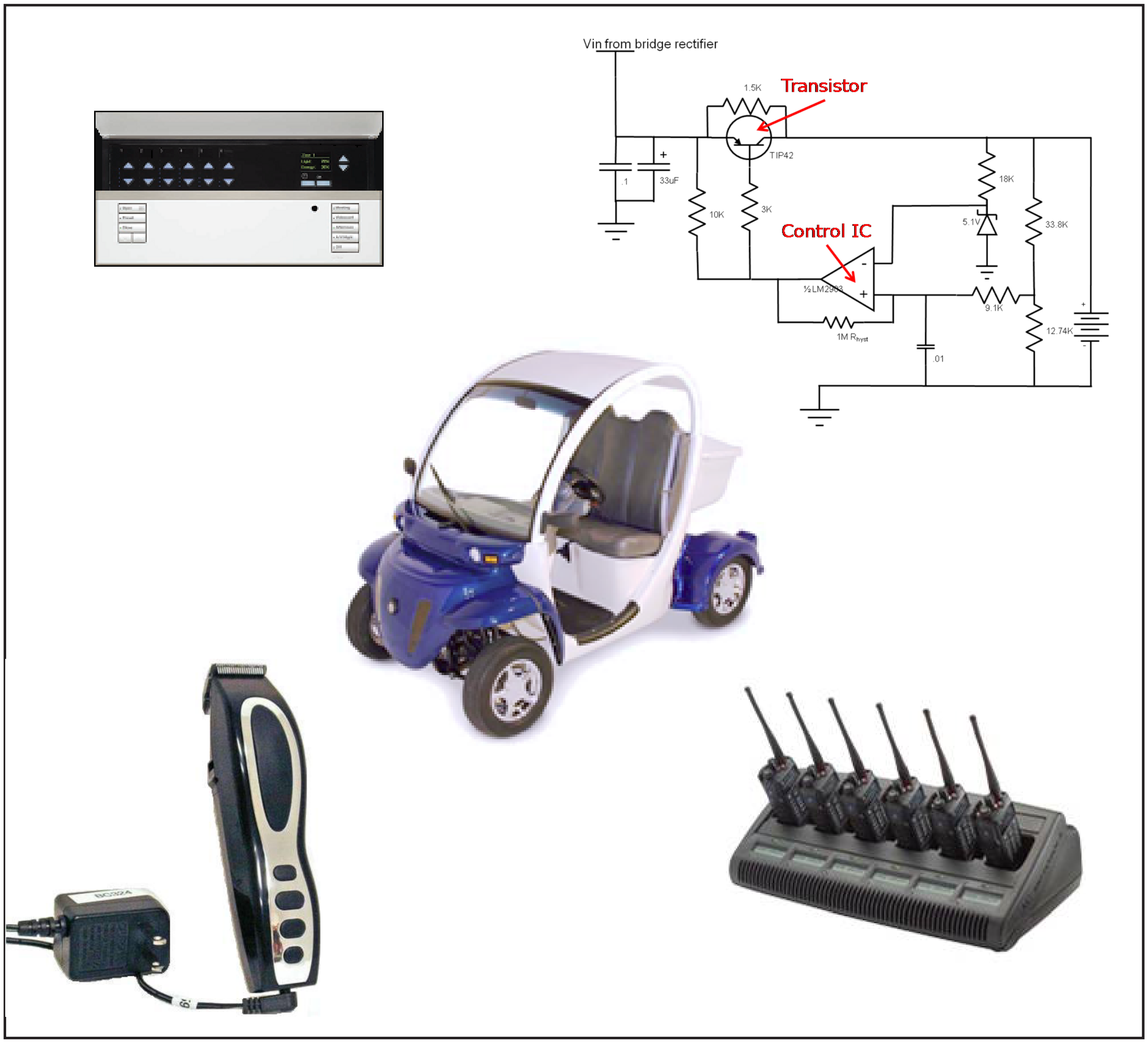
STAFF REPORT

CALIFORNIA
ENERGY
COMMISSION

Staff Analysis of Battery Chargers and Self-Contained Lighting Controls



2011 APPLIANCE
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PREFACE

On February 5, 2007, the California Energy Commission approved an Order Instituting Rulemaking to amend the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through Section 1608[1]). Subsequently, in its April 2, 2008, Scoping Order,[2] the Energy Commission's Efficiency Committee initiated Phase I of the *2008 Appliance Efficiency Regulations Rulemaking* and further divided Phase I into separate parts.

In Part B of Phase I, the Commission adopted test procedures for small and large battery charger systems. The scoping order noted that in the next phase of the Appliance Efficiency Rulemaking the Efficiency Committee expected to consider power usage regulations and requirements for battery chargers, as well as further amendments to the Appliance Efficiency Regulations, as appropriate.

In August 2010, the Efficiency Committee approved initiation of a Phase II rulemaking under the 2008 Scoping Order. Phase II continues the previous Phase I rulemaking with the goal to adopt regulations for battery charger systems that would rely upon the test procedure adopted in Phase I. On June 1, 2011, the U. S. Department of Energy (DOE) published a Final Rule amending its test procedure for consumer battery chargers. The DOE test procedure measures active charge, maintenance, and no-battery mode using the same method as described in Part 1 of the Energy Commission test procedure. The California investor-owned utilities (IOUs) have prepared a Codes and Standards Enhancement (CASE) report as a basis for considering efficiency regulations for these battery charger systems. The CASE report provides the analysis and recommendations that form the underlying basis for the proposed battery charger system regulations. The Energy Commission held a staff workshop on October 11, 2010, and provided a comment period to give stakeholders an opportunity to respond to the substance of the CASE report. An additional staff workshop was held March 3, 2011, and a Committee Workshop was held on May 19, 2011.

This proposed regulation includes efficiency regulations for active, maintenance, and no battery modes for small and large battery charger systems. In addition the proposed efficiency standards for larger battery charger systems includes power factor requirement. The proposed scope of the regulations includes both consumer products and nonconsumer equipment. The proposed regulations will not require manufacturers to alter the battery chemistry or product design of their products. The proposed regulations are based on consideration of the CASE report data, stakeholder comments, and on the preliminary data provided in the DOE's Technical Support Document (TSD) for federal battery charger regulations[3].

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1 All references to title are to the California Code of Regulations and references to section numbers are to Title 20 of those regulations, unless otherwise noted.

2 http://www.energy.ca.gov/appliances/2008rulemaking/notices/2008-04-02_COMMITTEE_SCOPING_ORDER.PDF

3http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/bceps_preanalysis_tsd.pdf

In addition to regulations for battery charger systems, the Phase II rulemaking also includes regulations for lighting controls. Lighting controls are currently regulated under Section 119 of the Energy Commission's Building Energy Efficiency Standards, found in Title 24, Part 6, of the California Code of Regulations. The proposal in Phase II is to move these regulations from an installation-based regulation in Title 24 to a sales-based regulation in the Appliance Efficiency Regulations in Title 20. The proposed lighting control regulations are design-based, as the energy savings cannot be measured within the device itself. Energy savings for lighting controls actually occur in lighting products that are external to the lighting controls. The energy savings analysis in this report will not show any saving for lighting controls.

ABSTRACT

This staff report discusses proposed amendments to the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through 1608). These regulations are part of the 2008 Appliance Efficiency Rulemaking, Phase II (Docket # 11-AAER-02).

This report presents California Energy Commission staff analysis of the cost-effectiveness and technical feasibility of the proposed battery charger system regulations, including statewide energy use and savings, and battery safety and related environmental issues. The staff report also summarizes state energy efficiency policy, proposed energy use measurement, and federal battery charger proceedings and test methods.

The proposed battery charger system regulations will result in significant energy and cost savings for California consumers. Battery chargers currently use an estimated 8,000 Gigawatt hours per year of electricity[4]. However, the actual useful amount of energy delivered to batteries is only 2,900 GWh/year. This difference of 5,100 GWh per year represents a significant potential for energy savings. The proposed standards would save 2,187 GWh a year in energy that is currently wasted as excess heat after the batteries are fully charged. In addition, based on an analysis of available data, Energy Commission staff concludes that the proposed battery charger system regulations are both cost-effective and technically feasible.

The method used in the development of energy savings estimates is shown in detail in Appendix A. The input data, assumptions, formulas, and calculations used to develop the energy savings and cost-effectiveness of the proposed standards are included to ensure transparency.

This report also includes language and justification for adding lighting controls regulations to Title 20. Currently, lighting controls are regulated under Section 119 of the Energy Commission's Building Energy Efficiency Standards, found in Title 24, Part 6. Many lighting control products sold in California do not meet the energy savings criteria set forth in Title 24. Title 20 requires that all regulated products sold in California must be certified to the Energy Commission. The proposed regulations would move self-contained lighting controls into Title 20 and leave lighting control systems comprised of multiple products in Title 24.

Keywords: Appliance Efficiency Regulations, appliance regulations, batteries, battery chargers, external power supplies, energy efficiency, lighting controls

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4 http://www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf

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Legislative Criteria

Section 25402, subdivision (c), of the Public Resources Code mandates that the California Energy Commission reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy by prescribing standards for minimum levels of operating efficiency of appliances whose use, as determined by the Commission, requires a significant amount of energy on a statewide basis. Such standards must be feasible and attainable and must not result in any added total costs to the consumer over the designed life of the appliance. In determining cost-effectiveness, the Commission considers the value of the energy saved, the effect on product efficacy for the consumer, and the life-cycle cost to the consumer of complying with the standard. The Commission also considers, when relevant, the effect on housing costs, the total statewide costs and benefits of the standard over its lifetime, the economic impact on California businesses, and alternative approaches and their associated costs.

Background

Battery Chargers: Energy Consumption on the Rise

The first consumer-grade nickel-metal hydride (NiMH) rechargeable battery for smaller applications appeared on the U.S. market in 1989. Lithium-ion batteries, which introduced a new level of energy density, became widely available in 1991. Recent developments in lithium-ion technology have expanded the rechargeable market into portable electronics as they allow for more flexible and compact designs. The introduction of these battery technologies made consumer-grade rechargeable products both economical and practical.

Since the early 1990s, the number of products sold with rechargeable batteries has grown significantly. Accordingly, the electricity consumed in charging rechargeable battery-operated devices has grown and there has been a significant increase in plug load electric consumption.

Examples of the many common products that operate on rechargeable batteries and that use battery chargers include:

- Personal care products.
- Mobile phones and cordless phones.
- Power tools.
- Consumer electronics such as MP3 players, laptop computers, audio recorders, and cameras.
- Off-road vehicles and forklifts.

There are about 170 million products with rechargeable batteries in California. These products require battery charger systems. While battery chargers in California consume roughly 8 billion kilowatt-hours (kWh) a year, only 2.9 billion kWh of that energy is actually delivered to the batteries. The potential for energy savings is in reducing the 5.1 billion kWh of annual loss while maintaining battery charger performance desired by consumers and industry. Substantial portions of these savings are achievable through improved battery charger design and could reduce this loss of electricity by more than half[5].

In 2006, Ecos Consulting (Ecos), RLW Analytics, and Lawrence Berkeley National Laboratory conducted a study with funding from the Energy Commission's Public Interest Energy Research (PIER) Program regarding plug load device use. The plug load is the energy consumed by an electrical or electronic device that is plugged into an electrical socket. This plug load study included battery chargers. This research sought to understand how and when consumers are operating the growing number of electronic devices in their homes and to identify existing potential energy savings opportunities. The research team surveyed 300 California families and metered plug loads in a subsample of 50 homes. The researchers obtained weeklong power and usage pattern measurements for nearly 700 devices in the subsample.[6] Battery chargers were one of the appliances studied. The study results identify significant opportunities for cost-effective savings by reducing standby losses. In 2010, the IOU's, through the Codes and Standards Enhancement (CASE) Initiative (also called CASE study) identified battery chargers as one of several important plug loads contributing to energy consumption in California homes.

To develop battery charger system regulations, the Efficiency Committee issued a request to manufacturers in November 2008 to submit test data for their battery charger systems using the California test procedure[7]. Ecos Consulting tested many battery charger systems and collected test data to develop the proposed regulations. The resulting analysis is presented in the CASE report.

Product Description

Battery charger systems are differentiated throughout this report into two categories – large and small – based on the overall power and energy of the system. Large battery charger systems are defined as those that draw peak power of greater than or equal to 2 kW. Small battery charger systems include those that draw less than 2kW. However, golf cart chargers fall within the scope of the U.S. Department of Energy (DOE) test procedure for consumer products regardless of the power draw, and under the proposed regulations are included in the small battery charger system category. The test procedures are fully described later in the report..

Federal law makes a distinction between consumer and non-consumer products; the proposed state regulations and this staff report do not make that distinction. A consumer product is defined in federal law[8] as a product that, to any significant extent, is distributed in commerce

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5http://www.efficientproducts.org/reports/bchargers/1270_BatteryChargerTechincalPrimer_FINAL_29Sep2006.pdf.

6 http://www.efficientproducts.org/documents/Plug_Loads_CA_Field_Research_Report_Ecos_2006.pdf

7http://www.efficientproducts.org/reports/bchargers/1413_Battery%20Charger%20System%20Test%20Procedure_V2_2_2_FINAL.pdf.

8 42 United States Code section 6291, subd. (1).

for personal use or consumption. A nonconsumer product falls outside the scope of that definition and covers products used primarily in industrial and commercial settings.

To capture the range of applicable devices sold in California, the existing regulations include the following definition for a "battery charger system"[9]:

> "'Battery charger system (BCS)' means a battery charger coupled with its batteries, or battery chargers coupled with their batteries, which together are referred to as *battery charger systems*. This term covers all rechargeable batteries or devices incorporating a rechargeable battery and the chargers used with them. Battery charger systems include, but are not limited to:

(1) electronic devices with batteries that are normally charged from AC (alternating current) line voltage or DC (direct current) input voltage through an internal or external power supply and a dedicated battery charger;

(2) the battery and battery charger components of devices that are designed to run on battery power during part or all of their operations;

(3) dedicated battery systems primarily designed for electrical or emergency backup;

(4) universal devices whose primary function is to charge batteries, along with the batteries they are designed to charge. These units include chargers for power tool batteries and chargers for automotive, rechargeable AA, AAA, C, D, or 9 V batteries, as well as chargers for batteries used in larger industrial motive equipment.

(5) The charging circuitry of battery charger systems may or may not be located within the housing of the end-use device itself. In many cases, the battery may be charged with a dedicated external charger and power supply combination that is separate from the device that runs on power from the battery.

The proposed regulations cover both internal and external power supply-driven products that have rechargeable batteries. Battery chargers generally fall into four types of form factors:

- Power supply and charge control circuitry, each in separate housings.
- Power supply and charge control circuitry in one housing, battery in separate housing.
- Charge control circuitry and battery in one housing, power supply in separate housing.
- Power supply, charge control circuitry, and battery all in the same housing.

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9 Title 20, Part 2, Article 4, Section 1602(w).

Efficiency Policy

Historically, California's energy efficiency regulations have resulted in significant reductions in California's energy consumption. Appliance energy efficiency is identified as a key component to achieving the greenhouse gas (GHG) emission goals of Assembly Bill 32 (Núñez, Chapter 488 statutes of 2006)[10] (AB 32) and those contained in the California Air Resources Board's *Climate Change Scoping Plan*[11]. They are also identified as key components in reducing electrical energy consumption in the Energy Commission's *2009 Integrated Energy Policy Report* (page 5) and the California Public Utilities Commission's (CPUC) *Energy Efficiency Strategic Plan*[12].

The CASE report identifies battery charger systems as a category of products with significant potential for GHG reductions and energy savings. The CASE report estimates that the proposed regulations would reduce 1.8 million metric tons (MMT) of carbon dioxide (CO_2) emissions, the equivalent of removing 138,000 cars from the road annually. These greenhouse gas reductions through energy efficiency are key strategy for attaining the goals of AB 32.[13]

The Commission is committed to accelerating the development of energy-efficient battery charger systems and other technologies through PIER-funded research and development and standards development. In addition, Commission staff is working to increase compliance with existing efficiency regulations through certification, enforcement, and outreach.

The Commission's Appliance Efficiency and PIER Programs are key components in preventing significant increases in electricity demand in California. Specifically, under the Commission's loading order, energy efficiency is the highest priority. Meeting efficiency goals is important because California's demand for electricity continues to grow, with statewide electricity consumption forecast to increase an average of 1.25 percent per year over the next decade while facing rapidly escalating fuel prices[14].

The combination of these pressures poses significant economic and social risk to California. Energy efficiency measures are uniquely poised to play a central role in meeting current energy and climate change challenges. This fact is acknowledged in virtually every discussion of GHG abatement opportunities, including McKinsey & Company's comprehensive 2007 review[15].

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10 http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.

11 http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf.

12 January 2011 update, Page 62, http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

13 http://www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pages 39 and 40.

14http://energynet.energy.state.ca.us/Erdad/Industrial_Agricultural_Programs/California_Energy_Efficiency_Strategic_Plan_June.pdf, Page 1-1.

15http://energynet.energy.state.ca.us/Erdad/Industrial_Agricultural_Programs/California_Energy_Efficiency_Strategic_Plan_June.pdf.

For example, California's appliance efficiency regulations adopted between 1975 through 2005 are estimated to have saved 18,761 GWh in 2010[16]. This represents 6.7 percent of California's electric load in 2010 and is roughly the amount of energy produced by California's two largest power plants. At the current electric power average rate of 14¢ per kilowatt/hour, California consumers saved about $2.68 billion in 2010 due to these regulations.

The Executive Summary of the *2009 IEPR*[17], notes that California's building and appliance regulations provide a significant share of energy savings from reduced energy demand. The 2008 Building Energy Efficiency Standards took effect on January 1, 2010, and require, on average, a 15 percent increase in energy efficiency savings compared with the 2005 Building Energy Efficiency Standards. The 2009 Appliance Efficiency Regulations became effective on August 9, 2009, and, as required by AB 1109, set new efficiency regulations for general-purpose lighting. The first phase applies to products manufactured on or after January 1, 2010. The Energy Commission adopted television regulations in 2009, and the Tier 1 standards in those regulations apply to televisions manufactured on or after January 1, 2011.

The Energy Commission must also adopt and implement building and appliance regulations that put California on the path to zero net energy residential buildings by 2020 and zero net energy commercial buildings by 2030. The *IEPR* further recommends that the Commission, in cooperation with the CPUC, the IOUs, and publicly owned utilities, devote sufficient resources to develop the capability to differentiate these future energy efficiency savings from energy efficiency savings that are already accounted for in the demand forecast[18].

On September 18, 2008, with support from the Governor's Office, the California Long-Term Energy Efficiency Strategic Plan was jointly adopted by the CPUC, the Commission, the California Air Resource Board, the state's utilities, local governments, and other key stakeholders. The Long-Term Energy Efficiency Strategic Plan is California's single roadmap to achieving maximum energy savings in the state between 2009 and 2020, and beyond[19].

The Long-Term Energy Efficiency Strategic Plan includes four "Big Bold strategies" as cornerstones for significant energy savings with widespread benefit for all Californians:

- All new residential construction in California will be zero net energy by 2020.
- All new commercial construction in California will be zero net energy by 2030.

16 http://www.energy.ca.gov/2009_energypolicy/index.html. Program forecasted for 2020 will grow to 27,116 GWh a year. This would represent 8.6 percent of projected load in 2020. At the current rate of 14¢ per kWh, this would save the state about $3.8 billion for 2020.

17 http://www.energy.ca.gov/2009_energypolicy/index.html. Program forecasted for 2020 will grow to 27,116 GWh a year. This would represent 8.6 percent of projected load in 2020. At the current rate of 14¢ per kWh, this would save the state roughly $3.8 billion for 2020.

18 http://www.energy.ca.gov/2009_energypolicy/index.html.

19 http://www.cpuc.ca.gov/NR/rdonlyres/14D34133-4741-4EBC-85EA-8AE8CF69D36F/0/EESP_onepager.pdf.

- Heating, ventilation and air conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate[20].

- By 2020, advanced products and best practices will transform the California lighting market. This transformation will achieve a 60-80 percent reduction in statewide electrical lighting energy consumption by delivering advanced lighting systems to all buildings

The above measures were selected based on potential impact on achieving energy efficiency savings, ability to stimulate construction, and ability to bring energy-efficient technologies and products into the market[21].

Zero Net Energy plan

To achieve the goal of zero net energy, it is critical to reduce the wasteful power consumption resulting from inefficient plug loads, which are beginning to equal loads such as heating, cooling, and lighting. Therefore, the CPUC's *Energy Efficiency Strategic Plan* includes development and adoption of broader appliance efficiency codes and regulations for plug loads such as copy machines, printers, battery chargers, televisions, and other devices.

The Energy Commission and CPUC, along with nongovernmental organizations, are working on developing milestones and pathways to achieve zero net energy goals. One of the most important efforts identified is to reduce power consumption from plug loads in all residential and commercial buildings. Battery charger systems are specifically identified as a critical component of plug load power reduction to help meet those goals.

Battery Charger Test Procedure

The proposed regulations for small battery charger systems require the measurement of energy consumption in active, maintenance, and no-battery modes. In December 2008, the Energy Commission adopted "Energy Efficiency Battery Charger System Test Procedure Version 2.2 dated November 12, 2008". Ecos and EPRI Solutions developed and published this test procedure[22]. This test procedure can be used to measure energy consumption in all of the above described battery charger modes. The test procedure consists of two parts: Part 1 applies to small battery charger systems, which have input power of 2 kW or less, and Part 2 applies to large battery charger systems, which have input power of more than 2 kW.

In addition to the California test method, there is also a federal test procedure adopted by DOE, which applies only to consumer products[23]. The Final Rule for this federal test procedure was

20 http://docs.cpuc.ca.gov/efile/RULINGS/85174.pdf Page 60.

21 http://docs.cpuc.ca.gov/efile/RULINGS/85174.pdf.

22 http://efficientproducts.org/product.php?productID=4

23 See 10 Code of Federal Regulations (CFR) 430.23(aa) and Appendix Y to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Battery Chargers.

published in the *Federal Register* on June 1, 2011[24]. Like the California test method, the DOE test procedure measures active, maintenance, and no-battery mode using the same method as described in Part 1 of the California test procedure. As a result of the adoption of DOE's test procedure, states are preempted from requiring testing or the use of any measure of energy consumption for consumer battery chargers other than that provided in the federal test procedure[25]. Under the proposed regulations, the small charger system standards will apply to some consumer and some nonconsumer products, while the large charger system standards will apply to nonconsumer products. Use of the federal test procedure to test small battery charger systems that are consumer products does not affect or change the existing battery charger system test data or the energy measurements for the proposed battery charger system regulations.

Part 2 of the California test procedure, which will apply to large battery charger systems (which are not consumer products), will not preempted by the federal test procedure. The test method measures power use in charging mode, maintenance mode, and no-battery mode. The test method also considers the various design schemes of batteries and includes strategies for testing each type. The three types of general battery charger system categories are:

- The charger, battery, and product are all contained within a single housing.
- The charger is external to the product, and batteries are moved from the product to the charger to recharge.
- The battery is not removed from the product, but the product must be connected to a charger or an external power supply to recharge.

Part 2 of the California test method also requires measurement of charge return factor and power conversion efficiency. Charge return factor is the ratio of ampere-hours into the battery over the ampere-hours out of the battery. Power conversion efficiency is the power out of the charger over the power into the charger. In addition, the large battery charger system test procedure requires measurement of power factor.

A light-emitting diode (LED) indicator or other types of functionalities that are part of the battery charger system charging process shall be tested as a part of the system and its energy consumption included in calculating the battery charger system consumption.

DC-to-DC chargers such as universal serial bus (USB) devices are included in the scope of the test procedure. The DOE Final Rule for the battery charger test procedure best explains how DC-DC chargers are handled for testing:

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24 *Federal Register*, Vol. 76, No. 105, pg. 31750.
25 See 42 USC 6297(a)(1)(A).

> "If a manufacturer packages its product with a wall adapter or the manufacturer recommends or sells a wall adapter for use with its product, the battery charger shall be tested with that wall adapter. If this is not the case and the product, such as a GPS device, only works with a DC input through either a car charger or a USB port, that device will be tested with the 5 V DC input that corresponds to the USB port configuration."[26]

Another important consideration when testing battery charger systems is the selection of batteries for the test. The test provides a decision path for finding the correct battery or series of batteries to use to test the battery charger system. For example, if the charger is always sold with a particular battery, it should be tested with that battery. For a few cases, such as multi-chemistry chargers, either the manufacturers can provide batteries with the battery charger system to the test lab, or test labs themselves can select suitable battery packs.

Lighting Control Test Method

The Energy Commission is not proposing any test methods for lighting controls. The proposed regulations for lighting controls are prescriptive and therefore can be evaluated without use of any specific test method(s).

Estimated Energy Consumption for Battery Chargers in California

Battery charger systems consume a significant and growing amount of energy statewide – 6,816 GWh per year[27] in2009. The stock and sales section of Appendix A shows large annual growth rates for battery charger system stock. According to the CASE report, California's battery charger system compound annual growth rate (CAGR) is estimated to be 10 percent in 2010[28]. Based on the CASE report's 2010 CAGR for battery charger system stock from 2009 through 2012, and using the CASE report's 2013 CAGR for 2013 through 2015, it is likely that 2015 per-capita battery charger system energy use would be 136 percent of 2009 levels if no efficiency improvements were made to battery charger systems.

The scope of the proposed battery charger system regulations encompasses many products and their associated loads. The CASE report categorizes these products into 16 groups, which encompass the majority of battery charger system products. The report estimates that the combined sale of battery chargers systems in California is 57 million units in 2009. The total stock of battery charger systems of all categories in California is estimated to be 170 million. Appendix A summarizes stock and sales estimates and provides per-unit electric consumption

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26 *Federal Register*, Volume 76, No. 105, page 31,757.

27 Appendix A, baseline energy use.

28 http://www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, page 32.

of battery charger systems in California. These figures were used in the staff analysis of savings and consumption.

Regulatory Approaches

ENERGY STAR®

The U.S. Environmental Protection Agency's (EPA) voluntary ENERGY STAR® program was the first government program to specify efficiency levels for battery chargers. However, the ENERGY STAR Version 1.0 specifications and test procedure address only a narrow range of small battery charger products in low power modes. The scope of the ENERGY STAR specification includes:

- Battery chargers packaged with portable, rechargeable products whose principal output is mechanical motion, light, air movement, or heat production, for example small home appliances, personal care products, power tools, flashlights, and floor care products.
- Stand-alone battery chargers sold with products that use a detachable battery, for example, some digital camera and camcorder designs.
- Universal battery chargers intended to charge standard sized batteries including AAA, AA, C, D, 9-volt.

The ENERGY STAR specifications for battery chargers are under revision, but no final specifications have yet been released. New ENERGY STAR specifications will help provide incentives for manufacturers to improve their products. This will lead to innovation in even the most efficient products in the battery charger market.

While ENERGY STAR is an important voluntary program, its current specifications are limited in scope and exclude active mode battery charger standard. The Energy Commission's proposed battery charger standards are comprehensive, include energy consumption measurements in all modes, and will realize significant energy savings. ENERGY STAR has announced its intent to incorporate active charge mode into a future battery charger specification and is interested in reviewing the test procedure that has been adopted by the Commission.

Commission staff considered the ENERGY STAR specification as a potential model for California standards but concluded that it does not take advantage of a large portion of the potential energy savings due to its limited scope in both covered products and in covered modes of operation.

Federal Regulations

Currently there are no federal energy efficiency standards for battery chargers. A provision requiring DOE to develop energy conservation standards for battery charger was included in the Energy Independence and Security Act of 2007 (EISA). The battery charger provisions in EISA are as follows:

> “Battery chargers.—No later than July 1, 2011, the Secretary shall issue a final rule that prescribes energy conservation regulations for battery chargers or classes of battery chargers or determine that no energy conservation standard is technically feasible and economically justified”.

The scope of the battery charger standards contemplated by DOE in its current rulemaking proceeding is limited to consumer battery chargers. The scope of the regulations proposed by the Energy Commission includes both consumer and nonconsumer battery charger systems.

DOE also released its framework document in June 2009 and a preliminary analysis Technical Support Document (TSD) in September 2010, laying out its approach for federal energy conservation standards for consumer battery chargers. Nonconsumer chargers are not in the scope of the federal proceeding. The TSD outlines an approach that differs in many ways from the CASE report, with the two critical divergences being in regulated metrics and product categories. The TSD proposes to regulate battery chargers based on an annual energy use calculation as opposed to the four metrics in the CASE report of 24-hour charge and maintenance maintenance mode, power factor, and no-battery mode. Using the annual energy use method would require an additional set of assumptions about product duty cycle. Energy Commission staff concluded that the proposed regulations cover a broad array of products with different duty cycles and that the DOE approach is unable to address this issue. In addition staff concluded that the duty cycles, closely tied to consumer behavior, are likely to evolve with time and that standards based on specific duty cycles are not appropriate.

To address the differences in duty cycles, battery capacities, and technologies, the TSD suggests ten product categories for consumer products as opposed to the Energy Commission’s three for small battery charger systems. Because the Energy Commission’s proposed regulations do not require duty cycle assumptions to calculate standards, unlike the TSD approach, there is no need to subdivide the standards to the degree of the DOE approach. The proposed standards ensure efficiency in all modes of battery charger system operation, regardless of duty cycle. The TSD approach only ensures efficiency for products when consumers use them according to imprecise duty cycle estimates. Staff has therefore proposed to take the regulatory approach outlined in the CASE report rather than the approach outlined in the TSD.

Staff estimates that, by October 2011, the battery charger regulatory proposals from DOE and California will be available. There is potential that these standards will vary in stringency, causing manufacturers of consumer products to meet different standards within a relatively short time frame. However, these differences will not require manufacturers to go through two separate redesign and production change processes because both standards will be available well before the respective effective dates, and manufacturers can design products to meet the more stringent standard.

The CASE Report

In October 2010, the IOUs submitted a CASE report to the Energy Commission for consideration of proposed standards. Staff has analyzed the proposal in the CASE report to determine whether it meets the legislative criteria for Commission prescription of appliance efficiency standards. Staff has proposed a modified regulation from the proposal contained in CASE report based on with stakeholder comments received during and after the staff and

Committee workshops on this CASE report and DOE TSD data. The sections below describe the staff analysis and modified proposal.

Stakeholder Input

Staff analyzed stakeholders' comments on the CASE report and previous versions of the proposed regulations, and considered other data and feedback provided by stakeholders. Based on this analysis, staff made appropriate and necessary changes to the proposed regulations from the CASE report to ensure that the standards are clear and specific.

Savings and Cost Analysis

The proposed battery charger system regulations represent a significant energy savings opportunity. In this section, Table 1 summarizes the first year and stock energy and peak reduction potential for the proposed regulations. First-year savings describe the annual savings associated with one year of sales. Stock savings describe the annual savings if all battery charger systems in use comply with the regulations.

According to the CASE report, battery charger system regulations have the potential to reduce peak demand by 361 MW. The model developed by staff and outlined in Appendix A estimates that if the all battery charger systems were compliant with the proposed regulations in 2013, California would save 2,187 GWh of energy per year. The existing stock number is based on the estimated number of all categories and types of battery charger systems currently in use in California. The existing stock replacement number refers to design life for each category type.[29] This is calculated by summing the stock savings for each product type. At a rate of $0.14 per kWh, these savings amount to $306 million a year in reduced utility costs. The savings do not include assumptions based on savings once a federal standard preempts the state standards, as the federal standards are currently unknown.

Staff has calculated the peak power reduction to be 2,187GWh/8,760 hours, which equals 0.25 GW, or 250 MW. This calculation is based on the simplified assumption that the load profile for battery charger systems is completely flat and energy would be evenly generated over the entire year to provide electricity for battery chargers.

Table 1: Statewide Annual Energy Savings*

Category	First year peak reduction (MW)*	First year energy reduction (GWh)	Stock peak reduction (MW)*	Stock energy reduction (GWh)	Stock Energy Savings ($)**
Small Charger Systems	43.3	379	210	1839.3	257 M
Large Charger Systems	3.1	26.9	39.7	347,3	49 M
Total	46.3	405.9	249.6	2186.6	306 M

* The first year and stock savings are totals of product categories in Appendix A.
**Stock Energy Savings assumes a cost of $0.14 per kWh.

The CASE report also shows that the proposed standards are highly cost effective, with payback generally occurring in the first year. Table 2 summarizes the unit cost effectiveness of the proposed standards based upon an aggregated version of Appendix A.

Table 2: Unit Energy Savings and Cost-Effectiveness

Category	Design Life (Years)	Annual Unit Energy Savings (kWh/year)	Incremental Cost of Improvement Per Unit ($)	Average Annual Present Value Savings ($)*	Simple Payback Period (Years)	Life Cycle Benefit ($)
Small Charger Systems	4.7	13.9	$0.80	$1.79	0.41	7.59
Large Charger Systems	15	3294	$342.86	375.84	0.91	5294.77

Table 2 is based on aggregated large charger units and small charger units weighted by sales and compliance.
*Present value calculated using 3 percent discount rate and $0.14 per kWh.

The values shown in Table 2 are sales and compliance weighted averages for the small and large charger system categories. The design life, incremental cost, and savings derived for the most common products in each category were aggregated into this table by averaging sales weight. The cost-effectiveness for each product category is analyzed in appendix A, table A-7. The average annual present value savings is calculated by totaling avoided expenses of $0.14 per kWh, discounted at 3 percent[30] for future savings, and dividing by the design life. The simple payback is the incremental cost divided by the average annual present value savings.

30 3 percent discount rate is based on
http://www.energy.ca.gov/appliances/2009_tvregs/documents/comments/TN%2053907%2011-2-09%20Discussion%20of%20Cost%20Effectiveness%20Calculations_1.pdf.

This payback estimate is conservative because the first-year savings will be greater than the discounted average savings. The life-cycle benefit is the difference between the average annual present value savings multiplied by the design life and the incremental cost of improvement per unit.

The savings estimates compare baseline product category energy consumption with the energy consumption under the proposed standards including current compliance rate estimates. For statewide estimates, these savings are multiplied by sales for first-year figures and by California stock for stock figures. The details of these calculations are available in Appendix A.

While the incremental cost of some products may increase depending on what approach manufacturers take to comply, the energy savings over the life of the products will more than recover these costs. Some examples of incremental cost included in CASE report include the following:

- Improving the efficiency of a low-power product like a cordless phone or power tool can cost less than $1.00 because changes can be as simple as swapping out linear power supplies with switch mode supplies. For a total incremental cost of less than $2.00, switch-controlled current regulating components, usually AC-to-DC converters, can be incorporated to significantly reduce maintenance and no-battery losses.
- A battery charger system can be totally redesigned and brought to market at an incremental manufacturing cost near zero. By replacing some components with more efficient ones, incremental costs near $0.40 are common.

The estimated costs of compliance for each product category are summarized in Appendix A, Table A-7. The CASE report estimates zero incremental consumer cost for products in categories where significant numbers of competing products already on the market meet the standard.

In conclusion, the proposed standards are clearly cost effective. As shown in Table 2, the cost to comply is more than offset by the energy savings over the life of the product. In addition, the reduction in electricity costs will save California rate payers (see Table 1) $306 million per year.

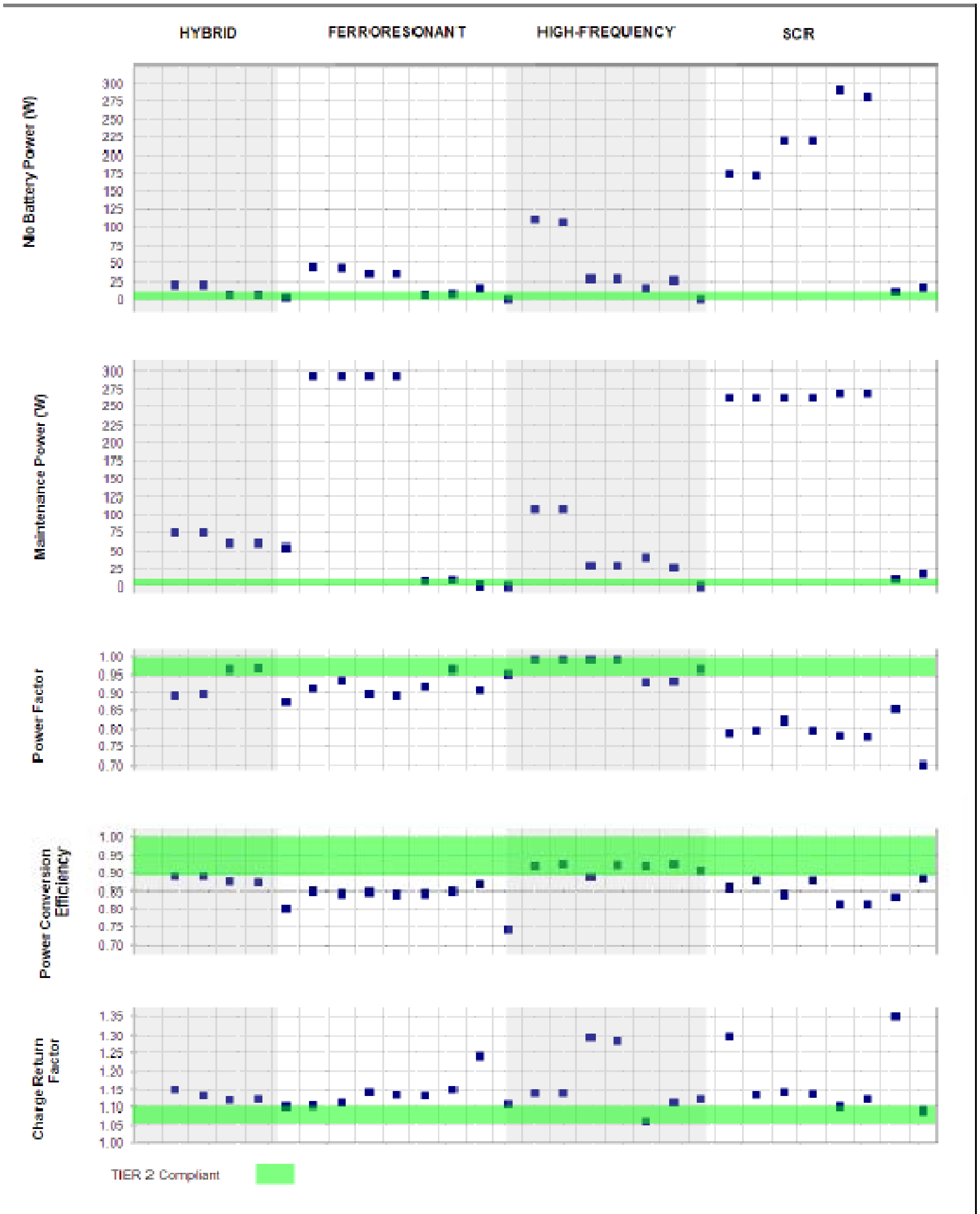
Battery Charger Regulations: Technical Feasibility

The proposed battery charger system regulations are based on the premise that, after the battery has been recharged, the battery charger should shut off the flow of electricity and provide low-maintenance charge current only on as-needed basis. Many battery-equipped products have a battery charger that continues to provide charge current to the battery after it is fully charged. The continuous current heats the fully charged battery resulting in wasted energy and potentially damaging the battery itself. There are battery charger systems currently on the market, across a wide variety of product categories and price levels, that have already addressed the problem by including inexpensive charge sensors and/or switches in their product designs. This capability can be implemented with inexpensive off-the-shelf technology and should not require extensive redesign of regulated products. Compliance can be achieved by changes to the battery charger circuitry, and by switching to a more efficient power supply, as needed.

Many battery charger systems on the market already meet the proposed standards at competitive price points. These products represent best practices for energy efficiency and clearly demonstrate the feasibility of the proposed standards. In fact, the proposed standards are based largely upon data from laboratory test results of battery charger systems on the market using the Energy Commission's test procedure.

Figure 1 below demonstrates the concept of choosing a standard that contemplates using existing efficient technologies to phase out the less efficient technologies. The red bars highlight products that meet the regulations, and the blue squares outside the line represent products that do not meet the proposed regulations. The proposed regulations are also technology-neutral in the sense that the levels are sufficiently stringent to improve efficiency but not so stringent as to eliminate an important battery charger type from the market.

Figure 1



* Test results shown correspond to 80% depth of discharge. * Squares at least 50% in band are compliant. Data shown from 15 unique chargers under varied test conditions.

Figure 8 of the CASE report, page 29. Note that proposed power factor requirements are less stringent

- The CASE report discusses the many strategies available to battery charger manufacturers and designers to significantly improve the efficiency of power conversion and charge control of each type of product. Small battery chargers can use linear and switch mode technologies, whereas large battery chargers can use switch mode, ferroresonant, and silicon-controlled rectifier (SCR) technologies. Currently many efficient battery chargers are available in the market which incorporate technologies to minimize energy losses when converting AC electricity from the utility grid to DC electricity typically used to charge batteries. There are many simple strategies to improve battery-operating efficiency, band battery chargers can be designed to meet the efficiency standards proposed in the regulations. The following performance factors must be considered to design an efficient charger:

- High power conversion efficiency.
- Low power in maintenance mode.
- Low power in no-battery mode.
- High power factor.
- Narrow range of charge return factor.
- Charger responding appropriately to partial discharge interrupted charging.

The CASE report uses a study conducted by Ecos and EPRI that found tremendous variation in the efficiency of battery chargers while charging or maintaining charge in connected batteries, and in the amount of power that chargers draw when no batteries are connected[31].

Based on that study, Ecos developed a technical report for the Energy Commission titled *Research Findings on Standards for Battery Charger Systems and Internal Power Supplies*[32]. This document identifies design choices that affect charger efficiency and notes the following components or methods that can lead to higher efficiency in battery charger systems:

- Use of higher-voltage systems.
- Use of efficient, switch-mode power supplies.
- Use of improved semiconductor switches to stop charging when batteries are full and maintain a low charge current for battery charge maintenance.
- Battery chemistries with higher columbic efficiencies[33] and lower self-discharge rates.
- Lower current rate for charge and discharge cycles.

Although all of these approaches can be applied to battery charger systems, the most cost effective approach will differ depending on the product type and manufacturer's design. Staff acknowledges that each business will need to consider multifaceted inputs to make this decision. Therefore, staff does not propose to mandate which path is preferred. The technology-neutral approach of the proposed regulations leaves the compliance path to the manufacturer.

31 http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-44_BatteryChargers.pdf.
32 http://www.energy.ca.gov/2007publications/CEC-500-2007-091/CEC-500-2007-091.PDF.
33 Coulombic efficiency is the ratio between the electrons removed from a battery during discharge compared with the electrons supplied during charging to restore the original capacity. Coulombic efficiency actually refers to charge (coulomb) efficiency, not energy efficiency.

Based on an analysis of the CASE report and DOE's TSD data, Energy Commission staff concludes there are no technical barriers preventing the development of battery charger systems with higher energy efficiency. In fact, in the savings and cost analysis portion of this report, staff has found that more efficient battery charger systems will result in a positive net financial gain to consumers.

The proposed regulations can be met by replacing the charge current controller in the battery charger circuitry with a comparator[34] and a transistor used as an on/off switch and/or to switch battery charger to a low maintenance charge mode. Component costs are generally below a dollar[35]. Highly efficient technologies exist today that could sharply reduce electric power consumption in battery chargers without negatively affecting the ability to charge batteries quickly and to full capacity. Smart chargers use a microprocessor to monitor temperature, voltage, and state of charge, which allows them to optimize the charging cycle. Numerous improvements in existing battery technologies have made batteries safer to operate, while increasing charge capacity and energy density, and reducing the charging time and charging losses. New developments and technologies in batteries are leading to an increase in battery use in electrical and electronic devices. An efficient battery charging system is a critical component in the successful operation of battery-operated devices. The proposed battery charger system regulations will help to transform the market by accelerating a shift to more efficient battery charger systems. Finally, increasing the market penetration of efficient battery charger systems in battery-operated products meets state policy goals by saving a significant amount of energy statewide, reducing electricity costs and peak load.

General Strategies to Improve Efficiency of All Charge Control Technologies

The proposed regulations for most battery charger systems can be met by implementing straightforward design changes. These concepts include turning the charger off when the battery is fully charged and implementing hysteresis[36] during charging. Many simple cost effective solutions are available to manufacturers to turn the battery chargers off after the batteries are fully charged.

The proposed regulations are technology-neutral and equally apply to all battery charger systems included in the scope. Manufacturers of rechargeable battery products can comply with

34 Comparator is a device that compares two voltages or currents and switches its output to indicate which is larger.
35 http://www.analog.com/en/amplifiers-and-comparators/current-sense-amplifiers/adm4073/products/product.html. (Example: Comparator d circuit has more functions than what is needed to control the charge current. Cost per unit is $0.99 based on an order of 1000 units.)
36 Hysteresis typically refers to turn-on and turn-off points in electrical, electronic systems. For example, if a thermostat set for 70 degrees turns on when the temperature reaches 68 and turns off at 72, the hysteresis is the range from 68 to 72. In battery chargers hysteresis can be implemented to turn off charger after the batteries are fully charged and set a range for periodically turning charger on and off to maintain full charge.

the proposed regulations without altering the way existing products use their batteries or the battery chemistry used in their products. There are many technologies available to manufacturers for improving the active, maintenance, and no-battery mode efficiency of battery chargers in these categories.

The most effective strategy to comply with the proposed standards is simply to turn off the flow of power after the battery is fully charged. The least efficient systems on the market today continue to charge fully charged batteries. This is detrimental both to the battery life, product safety, and consumer's electricity bills. Figure 2 below shows the profile of an inefficient battery charger system.

Figure 2: Charge Curve Black and Decker

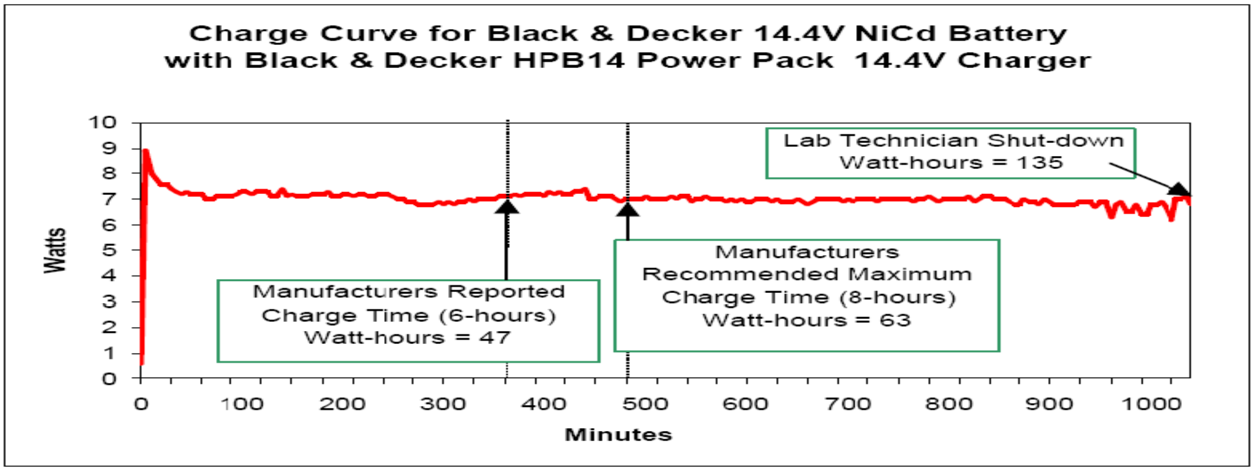


Figure 2 demonstrates the results of a test conducted by Ecos Consulting.

In the graph above, the battery charger system consumes about 0.5 watts in no-battery mode and an average of 7 watts in charge mode. During a 24-hour test, this system would consume 168 watt-hours of energy. The battery capacity is 36 watt-hours, yielding a result of 21 percent in 24-hour efficiency test, and would not meet the proposed efficiency standard. If the charger were to turn off after the maximum charge time, the system test would consume 64 watt-hours and a 56.25 percent 24-hour efficiency and would meet the proposed standards.

Another strategy is to prevent or reduce the rate at which fully charged batteries lose charge. All battery chemistries leak and lose charge over time after the battery is fully charged. This self-discharge rate varies by state of charge, chemistry, temperature, and battery design. The self-discharge is particularly acute at the maximum capacity of the battery and follows an exponential charge decay curve.

To keep batteries fully charged, a charger might incorporate a maintenance mode that re-energizes the batteries to replace the self-discharge losses. A modification to the system design can be made, to keep such batteries fully charged, by providing a low periodic maintenance charge to fully charge batteries. To accomplish periodic maintenance capability a battery charger system must incorporate a charge controller for transition from charge mode to low power periodic maintenance charge mode. Switching chargers off and on for periodic maintenance to reduce energy consumption can be accomplished by implementing hysteresis. A simple charge controller can be designed by using a comparator to read battery charge condition and an electronic switch to turn charge off or on[37]. Electronic switching can also be accomplished by using a timer, a temperature sensor, a voltage sensor, a transistor, or any number of other open or closed control systems. The cost of incorporating a charge control mechanism in a battery charger will be paid for by the energy savings generated, and the payback period for the incremental cost increase is less than the life cycle of the product[38].

Self-discharge rates are large over the first 24-hour period, but then stabilize to much lower rates. a 0.5 watt maintenance mode is feasible for products designed to charge high-capacity batteries. The extreme case is a system designed to charge batteries with a capacity of 1000 watt-hours, the maximum capacity within the scope of the proposed small charger regulations. Assuming a charge efficiency of 70 percent, a battery capacity of 1,000 Wh, and a self-discharge rate of 0.56 percent per day (extrapolated from a monthly self-discharge rate[39]), a reasonable power allowance for maintenance mode can be calculated as $1000 \times \frac{0.0056}{0.7 \times 24}$ yielding 0.33 watts. Paired with a power supply that consumes 0.17 watts in no battery mode this extreme case can meet the proposed standards.

Some systems are designed to counteract self-discharge by charging the battery constantly to maintain energy storage. These chargers are called "trickle chargers" and are the type of systems that will draw more power in maintenance mode than in no-battery mode. The larger the battery capacity of the battery, the more power is needed to maintain that battery charge. This concept is recognized in the proposed maintenance mode standards for both large and small battery charger systems. The maintenance-mode test measures the average power over the last four hours of the test, and the result is applied to a fully charged battery. In summary, the above solutions to address energy losses after a battery is fully charged have the following benefits:

- Lowering charge current reduces charge mode and maintenance-mode power levels and heating losses.
- Battery-sensing circuitry reduces the no-battery mode power, reduces unnecessary overcharge energy usage, improves charge return factor, reduces heat in the battery, and can extend battery life.
- Higher internal system voltage reduces resistive and conversion losses and may reduce system current. (Geist, Kameth, et al., 2006.)

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37 A comparator is a device that can compare two voltages or currents and switch its output to indicate which is larger.

38 http://www.energy.ca.gov/appliances/battery_chargers/documents/2011-03-03_workshop/presentations/Proposed_Standards_for_Battery_Chargers-Suzanne_Foster_Porter_and_Philip_Walters.pdf, Page 29.

39 Isidor Buchman, *Batteries in a Portable World*, 2nd Edition, Cadex Electronics, 292 pp, 2001: NiCd loses 40 percent in 3 months, NiMH loses 10 percent in 1 month, Li-Ion loses less than half that of NiCd and NiMH, so say ~0.15 percent loss/day, sealed lead acid loses 40 percent in 12 months; all daily self-discharge values are calculated assuming simple exponential decay.

- Reduced fixed energy consumption reduces no-battery mode power and energy usage overall.

In conclusion, the proposed regulations can be met without limiting the overall technical approach to battery charging. The following bulleted list of technological solutions details how these strategies can help improve the efficiency of both large and small battery charger systems.

- Linear Design
  - Replacing linear power supply with switch mode power supply can easily and cost-effectively improve the 24-hour efficiency of small chargers by nearly 15 percent. (Geist, Kameth, et al., 2006.) Any efficiency improvement in power conversion will cascade energy savings in all three modes of battery charger operation: charge, maintenance, and no-battery.
  - Using full-wave rectifiers instead of half-wave rectifiers can drastically improve efficiency. Full-wave rectifiers deliver twice the output power; therefore full-wave rectifiers are more efficient than half-wave rectifiers.
- Switch-Mode Design:

  Switch-mode chargers can be made more efficient through sophisticated design methods, including:

  - The most popular charge controller technology on the market today is Pulse Width Modulation (PWM). Charge controller ensures efficient charging and discharging of system batteries.

    PWM charge controllers provide a series of short charging pulses to the battery depending on battery state of charge. The charge controller continuously checks the state of charge inside the battery between each pulse to determine how fast or slow to send the charge pulses. Charge controllers are capable of varying the length, current, and voltage of the pulse. When the battery is low or nearly discharged, the charge pulses may be long and continuous, and as it becomes charged, the pulses become shorter. PWM technology, when used with nickel cadmium batteries, will improve the efficiency of nickel cadmium battery charging system.
  - Resonant switching configuration: Resonant switching configuration in charge mode can reduce switching losses in larger battery chargers with switch-mode power supplies. In this circuit design, power transistors switch on and off at the precise time that the voltage or current passes through zero, reducing heating loss in the transistors. (Geist, Kameth, et al., 2006.)
  - Synchronous rectification: Synchronous rectification can reduce voltage drop and thus power losses in the power supply by using a transistor to conduct during certain cycles of operation as opposed to a diode.
  - Periodic maintenance: In a switch-mode system, a switching-controlled energy delivery can provide periodic maintenance to batteries when used with battery voltage sensing circuitry, as opposed to unchecked battery maintenance.

- Ferroresonant
  - Ferroresonant chargers operate by way of a special component called a ferroresonant transformer. The ferroresonant transformer reduces the voltage from the wall outlet to a lower regulated voltage level while simultaneously controlling the charge current. A rectifier then converts the AC power to DC power suitable for the battery.

    Greater efficiency in ferroresonant chargers can be achieved by incorporating hybrid technology to improve the magnetic flux coupling in the transformer to improve power conversion efficiency. This technology significantly improves the efficiency of battery chargers
- Silicon-Controlled Rectifier (SCR)
  - SCR chargers can be made more efficient by reducing switching losses by incorporating higher switching frequencies.

    SCR chargers are likely to be supplanted by more technologically advanced and efficient high-frequency, insulated gate bipolar transistor (IGBT) based chargers. High-frequency chargers have much lower switching losses and thus better power conversion efficiency. Incorporating high efficiency switching significantly improves the efficiency of SCR battery chargers.

Battery Chemistry Compliance Pathways

Batteries are included as a part of the battery charging system. Battery design and battery chemistry affect the charging process and energy consumed by a battery while charging. Battery chemistries have unique properties but in many cases have similar enough characteristics to compete in the same products. Power tools and cordless phones, for instance, can be found using nickel cadmium, nickel metal-hydride, and lithium-ion batteries. However each of these chemistries has special characteristics that directly relate to energy consumption. Rechargeable batteries use one of the four main chemistries described below. Feasibility of the proposed standards and compliance strategies based on battery chemistries are discussed below.

Lithium-Ion

Lithium ion batteries have a very high charge acceptance and very low self-discharge. This allows the batteries to be efficiently charged and means that the batteries need little, if any, maintenance charge. However, lithium-ion batteries are susceptible to thermal runaway and will not tolerate overcharge. This means that they must be very precisely charged. While this also tends to lead to greater efficiency, it also requires safety and charge control circuitry which results in small additional fixed-load energy consumption. Nevertheless, many lithium-ion products meet the proposed regulations across a wide variety of capacities showing overall compliance feasibility. The primary path forward for lithium battery charger systems that do not comply with the proposed standards will be to reduce fixed loads. This can be accomplished by using improved power supplies and ensuring additional functionality is turned off during testing (as stated in the battery chargers test procedure).

Nickel Cadmium

Nickel cadmium batteries have a lower charge acceptance than lithium-ion and tend to have a higher self-discharge rate. These traits cause nickel cadmium batteries to require greater energy inputs to charge and additional energy to stay fully charged over extended periods. Nickel cadmium is far less sensitive to overcharge than lithium-ion and can sustain constant overcharge. This means that extremely simple charge control systems can be used. These simple control systems are less expensive but nearly always lead to overcharging nickel cadmium batteries and, therefore, less efficient battery charger systems.

Maintenance-mode performance of nickel cadmium battery charger systems varies greatly in the current market. The simplest systems provide a C/10 to C/50 current[40]. This keeps batteries full by constantly overcharging while not overcharging to the point that the battery will vent oxygen gas. However, nickel batteries can be kept charged using far less energy by minimizing this overcharge. As discussed in the general strategies section, this can be achieved by implementing charge termination that can detect when the battery is full. Also, much lower maintenance charge rates like C/128 for constant current and C/512 for pulsed current can be used to keep nickel chemistries full and ready for use[41]. These lower trickle rates will significantly reduce the power consumption of nickel cadmium charger systems and will also improve their 24-hour energy efficiency. The following two figures demonstrate the efficiency gains made possible by lowering maintenance mode through charge termination and lower trickle charge.

40 "C" is battery's capacity measured in Amp-hours. Most portable batteries are rated at 1C, meaning that a 1,000mAh battery that is discharged at 1C rate should under ideal conditions provide a current of 1,000mA for one hour. The same battery discharging at 0.5C would provide 500mA for two hours, and at 2C, the 1,000mAh battery would deliver 2,000mA for 30 minutes. 1C is also known as a one-hour discharge; a 0.5C is a two-hour, and a 2C is a half-hour discharge.
41 *Harding Battery Handbook For Quest® Rechargeable Cells and Battery Packs*, page 34, January 15, 2004.

Figure 3: Nickel Cadmium Charger System Without Charge Termination and Maintenance Power

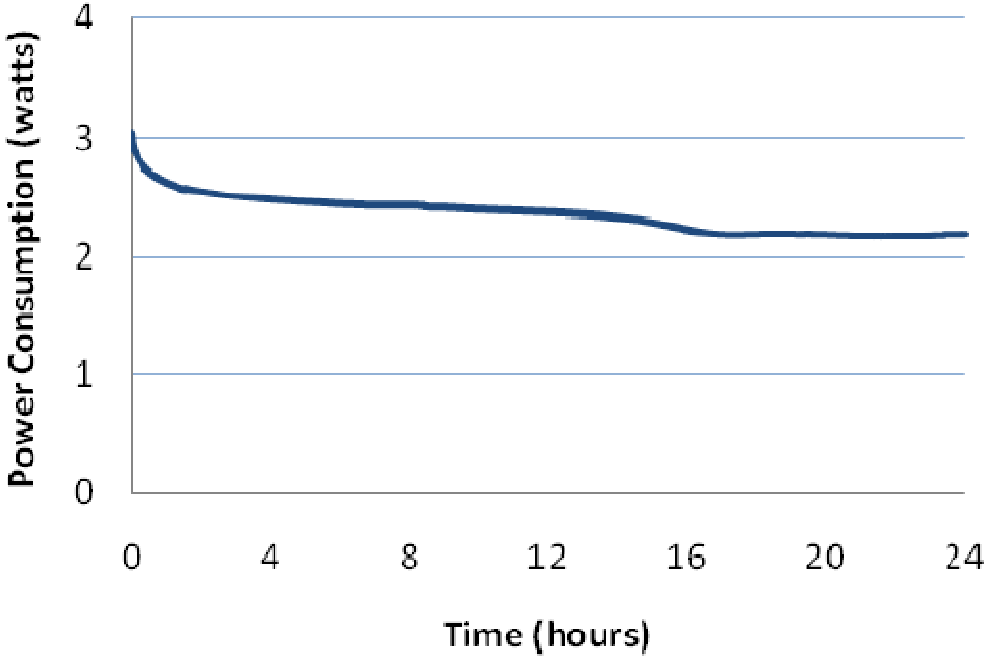
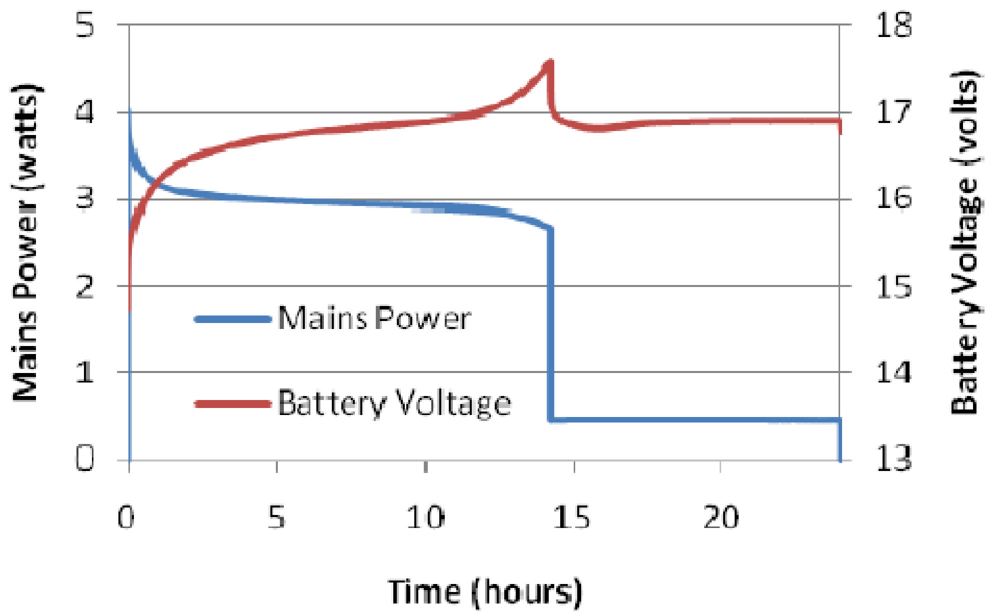


Figure 4: Nickel Cadmium Charger System With Charge Termination and Low Maintenance Power



Figures 3 and 4 are derived from a power tool teardown performed by PG&E's consultant Ecos. Implementing the lower trickle and charge termination reduced the maintenance power from 2.2 watts to 0.4 watts and improved the 24-hour energy efficiency by 6 percentage points.

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Nickel cadmium battery charger systems can also be paired with efficient power supplies that will allow manufacturers to provide greater maintenance power by offsetting it by lowering EPS fixed and variable losses.

Nickel cadmium battery charging efficiency can also be improved by implementing rapid charging. The battery charge acceptance can be improved from 50 percent at a C/7-C/10 rate to 90 percent for a C/1-C/3 rate[42]. Increasing the charge rate requires charge termination circuitry to avoid severe overcharge, which will permanently damage the battery. This is the same charge termination circuitry that can be used to reduce maintenance mode power.

Nickel-Metal Hydride

Nickel-metal hydride batteries are similar to nickel cadmium batteries and have lower charge acceptance than lithium-ion. Nickel-metal hydride batteries are also less tolerant of overcharge than nickel cadmium, and their performance will degrade with excessive maintenance power. Therefore, to avoid damage to the batteries and to save energy, nickel-metal hydride battery charger systems can terminate maintenance power over the course of the 24-hour test period. While self-discharge will occur during this period, the self-discharge can be countered using intermittent charging using voltage based charge control circuitry. The frequency of this intermittent charging can be as low as once a week, even for backup systems[43]. This maintenance strategy will improve the maintenance-mode performance of nickel metal hydride charger systems and the 24-hour energy consumption. Intermittent charging control will bring nickel-metal hydride charger systems into compliance in addition to improving battery life.

Lead Acid

Currently, there are three common lead-acid battery technologies: flooded, gel, and absorbed glass material (AGM). There are some significant differences among these lead-acid battery types in terms of features and construction.

Flooded, or wet cells, are the most common lead-acid battery-type in use today. The liquid lead acid electrolyte is free to move in the cell compartment.

Gel cells use a thickening agent like fumed silica to immobilize the electrolyte. The gel cells use slightly lower charging voltages than flooded cells.

Common charging methods used to charge AGM batteries are voltage limiting (VL) and current-limiting (CL).

Lead acid charging uses a voltage-based algorithm that is similar to lithium-ion. The charge time of a fully discharged sealed lead acid battery is 12–16 hours. With higher charge currents and multistage charge methods, the charge time can be significantly reduced, however, the

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42 *Harding Battery Handbook for Quest® Rechargeable Cells and Battery Packs*.
43 *Panasonic Nickel Metal Hydride Batteries Technical Handbook*, page 18.

topping charge may not be complete. Lead acid is sluggish and cannot be charged as quickly as other battery charger systems.

Lead acid batteries battery manufacturers recommend that lead acid batteries be charged in three stages: constant-current charge; topping charge (active mode); and float (maintenance mode) charge. The constant-current charge applies to the bulk of the charge and takes up roughly half of the required charge time; the topping charge continues at a lower charge current and provides saturation; and the float charge compensates for the loss caused by self-discharge.

Inductive Charger Systems

The key difference between inductive charger systems and other systems is in their wireless power supply. In some products, such as toothbrushes, wireless power delivery provides a great deal of utility, like avoiding contact corrosion products that are particularly exposed to water and chemicals. However, this method of power delivery is inherently less efficient than direct wiring. This applies to charge efficiency, maintenance mode, and no-battery modes. To ensure the feasibility of implementing of inductive charging in this specific case, Energy Commission staff has proposed alternative compliance option for inductive chargers.

This option restrict active charge mode energy consumption to an average of less than 1 watt over a 24 hour test period and limits both the maintenance and no battery mode to a maximum demand of 1 watt at any time during the test cycles.

Backup and Uninterruptable Power Supply (UPS)

UPSs are classified in three main categories as follows:

1. VFD Class UPS: A system in which the output voltage depends on input voltage and frequency (IEC 62040-3 ed.2). VFD class generally refers to passive standby (off-line) systems.

2. VFI Class UPS: A system in which the output voltage is independent from input voltage and frequency (IEC 62040-3 ed.2). VFI class generally refers to double conversion on-line types.

3. VI Class UPS: a system in which the output voltage is independent on the input voltage (IEC 62040-3 ed.2), but depends upon the input frequency. VI class generally refers to line interactive type.

Voltage and frequency dependent (VFD) UPSs are included in the scope of proposed battery charger system regulations. The proposed regulations require that UPSs be tested in only maintenance and standby mode. Many of the same efficiency improvements that can be made to small battery charger systems in general can also be applied to backup and uninterruptable power supplies.

UPSs that are voltage and frequency independent (VFI) and voltage independent (VI) are excluded from the scope.

Exception for Replacement À la Carte Chargers

An à la carte charger system is made available by a manufacturer directly to a consumer or to a service or repair facility, after and separate from the original sale of the product, that requires the battery charger system as a service part or spare part, shall not be required to meet the standards proposed regulations until January 1, 2018

Power Factor Standard and Compliance Strategies

An AC power supply draws power from the wall plug and converts it to DC. The draw of AC power in a nonlinear form results in significant loss of power because the power supply draws more current than it actually needs to power the battery charger system. The additional power drawn remains unused and generates a voltage current distortion, which results in excess heating the building's distribution wiring that connects the breaker box and the outlet. Poor power factor results in energy loss in building wiring because excess energy is converted and dissipated into heat.

Many battery charger systems use power supplies that are nonlinear, and these power supplies have a low power factor of~0.4 that can easily be improved. Devices that have a low power factor result in significant wiring power loss. It is essential to include requirements for a minimum power factor for some chargers, and therefore the Energy Commission has included proposed regulations to address power factor, which are estimated to save between 150 and 575 GWh per year[44].

The above issues can be addressed by improving power factor, which for large battery charger systems is relatively straightforward and low cost. Specifically, the strategy for improving power factor is to reduce current and voltage distortion (created by the charger), as well as reduce the peak current (drawn by the charger).

LED Indicator Lights Allowance

LED indicator lights are part of a battery charger system as they indicate the status of the battery's charge state. The energy consumption of LED indicator lights can vary from 0.01 to 0.05 watts per LED[45]. During testing, one LED per battery needs to be on at a time to indicate the mode of charge, and for no-battery mode there should be no LED indicator light on, and the LED energy consumption should be zero. The proposed limit on power consumption was designed so that no additional allowance is neededfor the additional functionalities such as LED indicator lights.

44 *CASE Initiative Analysis of Standards Options for Battery Charger Systems.*
45 http://www.energy.ca.gov/appliances/battery_chargers/documents/2011-03-03_workshop/presentations/Proposed_Standards_for_Battery_Chargers-Suzanne_Foster_Porter_and_Philip_Walters.pdf, Page 20.

Battery Safety and Environmental Issues

Proper charging of a battery pack is essential to ensure the safe operation and efficient charging of portable electronic devices. Sufficient voltage and current at an appropriate charge must be supplied to the batteries so that cells can be fully charged and perform optimally. Too much charge delivered too quickly to a battery can permanently damage the battery and make some batteries unsafe due to overheating. An intelligent battery charger system design allows chargers to charge batteries precisely and safely and allows chargers to efficiently use energy in both charge and maintenance modes.

Efficient charging may increase the lifespan of batteries because it reduces damage to battery cells caused by heat and undesirable electrochemical reactions associated with a constant trickle charge to the battery. Heat and undesirable electrochemical reaction result in battery material loss and chemical changes that affect the electrical performance of the battery cell and cause irreversible damage to the cell. Improving the lifespan of the battery helps in reducing the amount of chemical waste generated from batteries.

Today, most widely used batteries in portable devices are nickel-metal hydride and lithium-ion. This is partially because nickel-metal hydride has become cheaper and Li ion batteries are lighter weight than the formerly dominant nickel cadmium chemistry. Nickel cadmium and sealed lead acid (SLA) batteries are still used in many applications, and the material inside of them are hazardous and toxic. Lithium-ion and nickel-metal hydride have low toxicity and are less hazardous. It is environmentally advantageous regardless of chemistry to increase the longevity of battery life and reduce the volume of batteries entering landfills or otherwise discarded.

The widespread use of batteries has created many environmental concerns, such as toxic metal pollution. In 1996, Congress passed the "Mercury-Containing and Rechargeable Battery Management Act" that banned the sale of mercury-containing batteries in the United States with an exception for small button cell batteries. California prohibits the disposal of rechargeable batteries in solid waste and requires recycling of cell phones. The rechargeable battery industry has nationwide recycling programs in the United States, with drop-off points at many local retailers.

Proposal for Battery Charger Regulations

Energy Commission staff have analyzed the approach proposed in the CASE report and evaluated the cost-effectiveness and feasibility of implementing the proposed regulations in California. Staff has determined that the dollar savings resulting from reduced energy consumption under the proposed standards are greater than the cost of compliance, as shown in the staff analysis in Appendix A. In addition, staff has found that the proposed standards are attainable through multiple low cost, off-the-shelf technologies, as demonstrated in the technical feasibility section of this report. Staff has also determined that the fundamentally different approach between the proposed California standards that DOE is proposing under its TSD would lead to lower energy savings for California. Based on these conclusions, the proposed standards for the primary modes of operation of battery charger systems are both cost-effective and technically feasible and will improve the energy efficiency of battery chargers systems by at least 40 percent.

Staff does not propose less stringent standards as they would result in lower energy savings than could be cost-effectively achieved at a higher stringency. Neither did staff propose standards that are significantly more stringent as they would not have been as cost-effective as the current proposal or would have required a later implementation date to allow manufacturers additional time to comply. More specifically, the proposed standards cover a wide variety of products; a more stringent standard may be feasible for many of these products, but for some products a more stringent standard would not have been cost-effective. This would have reduced the overall effectiveness of the regulations and, in the case of some products, may violate statutory criteria regarding cost-effectiveness and feasibility. Staff believes that the standards are set at a level that will achieve significant increases the energy efficiency of battery charger systems with existing low cost, off-the-shelf technologies and will not affect the efficacy of battery-powered devices.

Battery chargers systems were identified in an Ecos study[46] funded by the Energy Commission's Public Interest Energy Research (PIER) Program as a class of appliances that wastes a significant amount of electricity in California, and that represented a potential source of large energy savings statewide. The proposed standards in the CASE report are based on battery charger system active, maintenance, and no-battery mode test data. Additionally, the CASE report analyzed battery charger systems' market data, product duty cycle, product design life, and technical feasibility. The CASE report recommended that the Energy Commission adopt would reduce electric power demand in California by roughly 2,186 GWh per year.

Based on its independent analysis of the best available data, including the CASE report and DOE TSD data, Energy Commission staff concluded that the proposed regulations would be both cost-effective and feasible.

The proposed efficiency standards for small battery charger systems, inductive charger systems, and battery backup and uninterruptable power supplies would apply to products manufactured on or after January 1, 2013, for consumer products and January 1, 2017, for non-consumer products. Proposed standards for large battery charger systems would apply to products manufactured on or after January 1, 2014.

The proposed large battery charger system standards are set forth in Table 3 below. The first standard, called "Charge Return Factor," measures the amount of energy applied to the battery versus the amount of energy extracted from that battery. The "Power Conversion Efficiency" is the systems' efficiency in converting high voltage alternating current into lower voltage direct current and measures the losses occurring in the circuitry during charging. "Power Factor" is a measure of how well the system is able to harmonize with the utility's 60-Hertz cycle. "Maintenance power" is the amount of power the system draws to keep a battery at full charge. Energy losses in maintenance mode are in both the charger circuitry and the battery. "No

46 http://www.energy.ca.gov/2007publications/CEC-500-2007-091/CEC-500-2007-091.PDF.

battery power" is the amount of power the system draws when no battery is attached at all and the charger is in standby mode

Table 3: Large Charger Proposed Regulations

Performance Parameter		Standard
Charge Return Factor (CRF)	100 percent, 80 percent depth of discharge	CRF ≤ 1.10
	40 percent depth of discharge	CRF ≤ 1.15
Power Conversion Efficiency		Greater than or equal to: 89 percent
Power Factor		Greater than or equal to: 0.90
Maintenance Power (E_b = battery capacity of tested battery)		Less than or equal to: 10 + 0.0012 E_b W
No Battery Power		Less than or equal to: 10 W

The proposed regulations for small battery charger systems are similar to those for large battery charger systems. The power consumption limits are lower due to the smaller capacity of the chargers and batteries involved. In addition, the charge mode and maintenance mode of small battery charger systems are measured together over a 24-hour period rather than separately.

The proposed small battery systems standards for 24-hour charge and maintenance energy have been altered from the draft staff report and are separated into four battery capacity standards. The result is a continuous small battery charger system standard across the full range of products. The first segment is for very small capacity batteries and is a flat line based on requests by Wahl Clipper and the Association of Home Appliance Manufacturers (AHAM). The second segment, from 2.5 Wh to 100 Wh, has not changed in stringency and is the same as proposed in the draft staff report. After investigating the available data for small battery charger systems of larger capacity, staff found that there were further feasible and cost-effective energy savings, and so the slope was "flattened" at the 100 Wh capacity, and the slope is further flattened at the 1000 Wh capacity. These new flattened levels align better with the levels proposed in the DOE's preliminary analysis "improved efficiency" level rather than its "baseline efficiency" level.

The proposal has also been updated to combine maintenance and no-battery mode power requirements as proposed at the May 19 Efficiency Committee workshop[47]. This is being proposed to allow manufacturers some flexibility to improve energy savings and costs when implementing improvements to no-battery and maintenance mode.

47 http://www.energy.ca.gov/appliances/battery_chargers/notices/2011-05-19_Committee_Workshop_Notice.pdf, page 3.

Table 4: Small Charger System Proposed Regulations

Performance Parameter	Standard
Maximum 24-hour charge and maintenance energy (Wh) (E_b = capacity of all batteries in ports and N = number of charger ports)	For E_b of 2.5 Wh or less: 16 x N
	For E_b greater than 2.5 Wh and less than or equal to 100 Wh: 12 x N + 1.6 E_b
	For E_b greater than 100 Wh and less than or equal to 1000 Wh: 22 x N + 1.5 E_b
	For E_b greater than 1000 Wh: 36.4 x N + 1.486 E_b
Maintenance Mode Power and No-Battery Mode Power (W) (E_b = capacity of all batteries in ports and N = number of charger ports)	The sum of maintenance mode power and no battery mode power must be less than or equal to: 1x N+0.0021xE_b Watts

The proposed standards include an alternative compliance method for inductive charger systems. The alternative compliance method requires inductive chargers to use no more than 1 watt on average in each of the following tests: no-battery, maintenance, and 24-hour charge and maintenance. While inductive charger systems suffer inefficiencies in power transfer that other charging systems do not, for small personal care products these losses are necessary in high-moisture applications, such as electric toothbrushes, that are typically charged in bathrooms. Inductive charger systems may choose to comply with the alternate compliance standard or the small battery charger system standard in Table 4.

The proposed regulations include maintenance mode standards for battery backup and uninterruptable power supplies. The proposal encompasses only the maintenance mode for these products due to the duty cycle shown in Table A-4, which shows that these products operate nearly exclusively in this mode. The maintenance mode requirement for these systems is similar to what is being required for small charger systems that are not battery backup and uninterruptable power supplies, with the primary difference being the disregard for no-battery mode power.

Marking and Reporting

The Energy Commission requires certification of state- and federally regulated products as part of compliance with the Appliance Efficiency Regulations. The certification process requires that manufacturers submit data specified in Title 20, Section 1606, Table X for each unique model number. The same will be required for battery charger systems and self-contained lighting controls. The certification will also require that manufacturers of both battery charger systems and self-contained lighting controls sign a declaration that the products being certified comply with all applicable provisions of the Appliance Efficiency Regulations. These provisions include marking the products with information such as the manufacture date, model number, and manufacturer or brand name.

The proposed regulations also include specific marking requirements for battery charger systems. These requirements mandate that manufacturers label their products with the letters "BC" inside of a circle. If the product has nameplate of less than 1/2 square inch, the circle BC mark can be placed on the retail packaging and the product instructions. The marking is being proposed to aid compliance and enforcement. Similar marking on external power supplies has been useful in this capacity, and the marking will streamline compliance in the supply and retail chains.

Lighting Controls

Lighting controls are currently regulated under Section 119 of the Energy Commission's Building Energy Efficiency Standards, found in Title 24, Part 6, of the California Code of Regulations. The proposed regulations would move these requirements from the installation-based regulations in Title 24 to the sales-based regulations in the Appliance Efficiency Regulations in Title 20. The proposed lighting control regulations are design-based, as the energy savings cannot be measured within the device itself. Energy savings for lighting controls actually occur in lighting products that are external to the lighting controls.

Currently Title 24 requires that both manual and automatic lighting controls be installed with lighting systems. Because the products are required to be certified under the provisions of Title 20, but these products are not included in Title 20 regulations, they are not prohibited from being sold or offered for sale in California. By adding, the lighting control regulations to Title 20, such products cannot be sold or offered for sale in California unless certified by the Commission and included in the Appliance Efficiency Database. This transfer will help to achieve the goals of Assembly Bill 1109, (Huffman and Feuer, Chapter 534, statutes of 2007 (AB 1109) and other efficiency goals discussed in the policy section of this report. The proposed effective date for the lighting control regulations is January 1, 2013. This provides one year for lighting control manufacturers to certify their self-contained products.

Appendix A: Model for Battery Charger Standards

Appendix A discusses the information and calculations used to characterize battery charger systems in California, their current energy use, and potential savings. The source of information for these tables is the CASE report. After careful review, staff has altered some of the figures from the CASE report as appropriate to fit staff's approach to energy consumption and savings and to reflect preemption scenarios.

Stock and Sales

The 2009 stock, 2009 sales, 2010-estimated CAGR, and 2013-estimated CAGR were taken from the CASE report. The CASE report collected these numbers from a wide variety of sources, and these numbers are based on industry censuses and forecasts. The sales of handheld barcode scanners were reduced from the draft report levels to reflect comments submitted by Motorola[48].

Table A-1: Stock and Sales

Product	Stock 2009 (million)	Sales 2009 (million)	CAGR Sales 2010	CAGR Sales 2013	Sales 2010 (million)	Sales 2013 (million)	Stock 2013 (million)
Auto/Marine/RV	1.8	0.18	3%	3%	0.19	0.20	2.09
Cell phones	47.9	28.27	19%	2%	33.64	41.65	59.10
Cordless phones	20.5	3.21	-10%	-9%	2.89	2.15	13.30
Personal audio electronics	29.8	10.52	12%	2%	11.78	13.73	31.60
Emergency systems	5.3	1.3	0%	0%	1.30	1.30	5.40
Laptops	16	4.57	29%	12%	5.90	9.54	24.40
Personal care	8.7	1.84	4%	3%	1.91	2.11	9.68
Personal electric vehicles	0.1	0.04	18%	24%	0.05	0.09	0.220
Portable electronics	10.3	2	9%	18%	2.18	3.31	18.50
Portable lighting	1.2	0.01	1%	1%	0.01	0.01	1.20
Power tools	15.3	2.87	5%	5%	3.01	3.49	18.60
Universal battery charger	0.9	0.11	3%	3%	0.11	0.12	1.00
Golf cart/ electric carts	0.175	0.017	16%	11%	0.02	0.03	0.248
Emergency backup lighting	7.9	2	0%	0%	2.00	2.00	7.85
Handheld barcode scanners	0.26	0.02	6%	7%	0.02	0.03	0.32

48 Motorola Comment Letter, March 15, 2011, page 2.

Two-way radios	0.6	0.028	0%	0%	0.03	0.03	0.600
Single phase lift-trucks	0.029	0.002	7%	1%	0.00	0.00	0.0298
Three phase lift trucks	0.074	0.005	7%	1%	0.01	0.01	0.0754

The sales for 2010 and 2013 are estimated by using the CAGR rates and 2009 sales. The 2010 sales are calculated by applying the 2010 CAGR to the 2009 sales figures. The 2013 sales are estimated by using the 2010 CAGR for 2010 and 2011 and the 2013 CAGR for 2012 and 2013. The equations can be expressed as follows:

$$Sales2010 \quad = Sales_{2009} \times (1 + CAGR_{2010})$$

$$Sales_{2013} = Sales_{2009} \times (1 + CAGR_{2010})^2 \times (1 + CAGR_{2013})^2$$

Compliance Rates

The staff report incorporates the compliance rates estimated by the CASE report with an increase in estimated cell phone compliance. These values are as follows

Table A-2: Compliance Rates

Market Segment	Product	Compliance
Small Charger System	Auto/Marine/RV	0%
Small Charger System	Cell Phones	90%
Small Charger System	Cordless Phones	0%
Small Charger System	Personal Audio Electronics	90%
Small Charger System	Emergency Systems	10%
Small Charger System	Laptops	10%
Small Charger System	Personal Care	0%
Small Charger System	Personal Electric Vehicles	10%
Small Charger System	Portable Electronics	10%
Small Charger System	Portable Lighting	0%
Small Charger System	Power Tools	10%
Small Charger System	Universal Battery Charger	50%
Small Charger System	Golf Cart/ Electric Carts	50%
Small NC	Emergency Backup Lighting	50%
Small NC	Handheld Barcode Scanners	50%
Small NC	Two-Way Radios	50%
Large charger System	Single Phase Lift-Trucks	0%
Large Charger System	Three Phase Lift Trucks	0%

Design Life

The design life is an estimate of the length of a product's typical operation usefulness. The design life figures were taken from the CASE report and are shown below.

Table A-3: Design Life

Battery Charger Size	Type	Design Life/years
Small Charger System	Auto/Marine/RV	10
Small Charger System	Cell Phones	2
Small Charger System	Cordless Phones	5
Small Charger System	Personal Audio Electronics	3
Small Charger System	Emergency Systems	7
Small Charger System	Laptops	4
Small Charger System	Personal Care	5
Small Charger System	Personal Electric Vehicles	9.7
Small Charger System	Portable Electronics	5.2
Small Charger System	Portable Lighting	10
Small Charger System	Power Tools	6.5
Small Charger System	Universal Battery Charger	8
Small Charger System	Golf Cart/ Electric Carts	10
Small NC	Emergency Backup Lighting	10
Small NC	Handheld Barcode Scanners	8
Small NC	Two-Way Radios	8
Large Charger System	Single Phase Lift-Trucks	15
Large Charger System	Three Phase Lift Trucks	15

Duty Cycle

The duty cycle is an estimate of consumer behavior for battery charger systems. It is directly tied to how often a product is used and how long it takes to charge the battery. For some products that use backup batteries, it is assumed that the battery will only rarely be charged as the product nearly always is connected to a power line and only in rare cases of emergency needs to be recharged. The duty cycles used for this staff report are slightly altered from the figures in the CASE report. The duty cycle for personal care products was altered to match the DOE TSD estimates and to address comments made by personal care product manufacturers[49].

The duty cycles represent current average usage to make meaningful estimates of product energy consumption and savings. These figures rely on metering and behavior studies, where possible, and use reasonable estimates where this type of information is unavailable.

49 Phillips Electronics Comment Letter, March 15, 2011, page 3.

Table A-4: Duty Cycle

Product	Charge %	Maintenance %	No Battery %	Unplugged %
Auto/Marine/RV	2%	78%	6%	15%
Cell Phones	5%	30%	19%	46%
Cordless Phones	31%	56%	9%	4%
Personal Audio Electronics	6%	25%	35%	33%
Emergency Systems	0%	99%	0%	0%
Laptops	6%	56%	30%	8%
Personal Care	5%	36%	6%	53%
Personal Electric Vehicles	37%	28%	35%	0%
Portable Electronics	1%	10%	1%	88%
Portable Lighting	1%	99%	0%	0%
Power Tools	4%	48%	15%	32%
Universal Battery Charger	1%	66%	17%	17%
Golf Cart/ Electric Carts	37%	47%	16%	0%
Emergency Backup Lighting	0%	99%	0%	0%
Handheld Barcode Scanners	13%	52%	35%	0%
Two-Way Radios	19%	31%	50%	0%
Single Phase Lift-Trucks	45%	32%	24%	0%
Three Phase Lift Trucks	98%	0%	2%	0%

Baseline Energy Use

The power consumption assumptions for battery charger system categories are derived from the CASE report. The CASE report relies on extensive product testing done by Ecos on existing battery charger systems. The charge mode power has been slightly altered from the CASE report to better match the test data that is reported in 24-hour energy into instantaneous power. Estimated annual energy consumption per product is derived using a combination of the power of the various modes and the duty cycles of those modes. For example, the annual energy consumption of charge mode is calculated by multiplying charge mode power by charge mode duty cycle and by the number of hours in a year. The annual energy consumption for a given product was thus calculated as follows:

$$E_{annual} = \left(P_{charge} \times D_{charge}\right) + \left(P_{maint} \times D_{maint}\right) + \left(P_{no\ bat} \times D_{no\ bat}\right)$$

Note: Unplugged duty cycle and power are not included because they do not contribute to annual energy use. Because the unplugged power is always zero, the factor is not relevant to the equation.

Table A-5: Base line Energy Use

Product	Charge (W)	Maintenance (W)	No Battery (W)	Percent At Peak	Annual Energy Consumption (Kwh Per Device)
Auto/Marine/RV	214	41.9	49.3	21%	343.06
Cell Phones	3.9	0.5	0.3	28%	3.48
Cordless Phones	2.7	2.2	1.7	95%	19.46
Personal Audio Electronics	2.1	0.5	0.1	16%	2.50
Emergency Systems	7	2.9	2.5	100%	25.38
Laptops	27.1	3	1.9	32%	33.52
Personal Care	1.2	1	0.9	80%	4.15
Personal Electric Vehicles	230	34.1	33.9	31%	931.17
Portable Electronics	9.2	2.5	0.9	6%	2.89
Portable Lighting	1.8	1.6	0.4	70%	13.98
Power Tools	17.5	3.5	1.8	30%	23.35
Universal Battery Charger	7.1	1.1	0.9	26%	8.16
Golf Cart/ Electric Carts	620	103	1.6	14%	2,439.95
Emergency Backup Lighting	2.2	1.6	1.6	100%	13.99
Handheld Barcode Scanners	11.2	3	0.2	46%	26.59
Two-Way Radios	5.3	2	0.9	6%	18.09
Single Phase Lift-Trucks	2000	50	50	19%	8,169
Three Phase Lift Trucks	5600	88.5	33.5	100%	48,038
Total GWh/yr					**6816**

Compliant Energy Use

The power consumption of compliant products is estimated based on minimum requirements to meet the proposed regulations. Some products were assumed to consume exactly the minimum power to comply with this standard. In a few cases, the baseline power for a given mode was already less than the standard. In these cases, the report does not assume that power will increase, but rather that it will remain the same. The annual energy consumption is calculated using the same method as baseline energy use.

Table A-6: Compliant Energy Use

Product	Charge (W)	Maintenance (W)	No Battery (W)	Annual Energy Consumption (Kwh/Device)
Auto/Marine/RV	118.1	1.82	0.3	29.16
Cell Phones	2.8	0.5	0.3	3.03
Cordless Phones	1.1	0.6	0.3	6.06
Personal Audio Electronics	1.2	0.5	0.1	2.01
Emergency Systems	4	1.08	0.3	9.51
Laptops	24.6	0.69	0.3	16.70
Personal Care	0.6	0.6	0.3	2.34
Personal Electric Vehicles	120	2.22	0.3	394.33
Portable Electronics	8.4	0.65	0.3	1.18
Portable Lighting	0.7	0.61	0.3	5.36
Power Tools	14.7	0.66	0.3	8.4
Universal Battery Charger	3.9	0.61	0.3	4.23
Golf Cart/ Electric Carts	485.7	13.2	0.3	1,632.33
Emergency Backup Lighting	1	0.62	0.3	5.44
Handheld Barcode Scanners	3.2	0.61	0.2	6.92
Two-Way Radios	3.8	0.61	0.3	9.23
Single Phase Lift-Trucks	1770	36.4	10	7,136.53
Three Phase Lift Trucks	5111	50.8	10	43,839.52

Costs and Savings

The cost assumptions for this table are from the CASE report. The unit energy savings are calculated by subtracting the compliant energy use from the baseline energy use.

$$E_{annual\ savings} = E_{annual\ baseline} - E_{annual\ compliant}$$

Unit cost savings (benefits) are calculated by multiplying the annual energy savings by $0.14 per kWh and by the discounted design life.

$$B_{energy\ savings} = \$0.14 \times E_{annual\ savings} \times L_{discounted\ design}$$

Net unit savings are calculated by subtracting costs from benefits.

$$B_{net} = B_{energy\ savings} - C_{compliance}$$

Current stock consumption is calculated for each product by multiplying its annual baseline energy consumption by its 2009 stock.

$$E_{stock} = E_{annual\ baseline} \times N_{2009\ stock}$$

Stock energy savings is calculated for each product by multiplying its unit energy savings by its 2009 stock and by its non-compliance rate. The non-compliance rate is 100% minus its compliance rate.

$$B_{stock} = B_{energy\ savings} \times N_{2009\ stock} \times (1 - R_{compliance})$$

The energy savings of first year sales is calculated in a similar manner to stock energy savings except by using 2010 sales rather than 2009 stock.

$$B_{stock} = B_{energy\ savings} \times N_{2010\ Sales} \times (1 - R_{compliance})$$

Benefit to cost ratio is calculated by dividing the unit cost savings by the unit cost of compliance.

Table A-7: Costs and Savings

Product	Unit Incremental Cost Increase	Unit Energy Savings (Kwh/yr)	Unit Cost Savings	Net Unit Savings	Stock Energy Savings (Gwh/yr)	Energy Savings Of First Year Sales (Gwh)	Benefit/Cost
Auto/Marine/RV	$10.00	313.91	$384.65	$374.65	656.07	63.6	38.5
Cell Phones	$0.00	0.45	$0.12	$0.12	2.67	1.88	N/A
Cordless Phones	$0.40	13.40	$8.84	$8.44	178.26	28.86	22.1
Personal Audio Electronics	$0.00	0.49	$0.20	$0.20	1.56	0.68	N/A
Emergency Systems	$3.00	15.87	$14.22	$11.22	77.14	18.57	4.7
Laptops	$0.50	16.82	$9.00	$8.50	369.36	144.41	18
Personal Care	$0.40	1.81	$1.19	$0.79	17.54	3.83	3
Personal Electric Vehicles	$12.00	536.83	$657.81	$645.81	106.29	41.38	54.8
Portable Electronics	$0.40	1.71	$1.13	$0.73	28.22	5.10	2.8
Portable Lighting	$0.40	8.62	$10.56	$10.16	10.34	0.99	26.4
Power Tools	$0.55	14.95	$11.65	$11.10	250.30	46.94	21.2
Universal Battery Charger	$0.40	3.93	$3.96	$3.56	1.96	0.24	9.9
Golf Cart/ Electric Carts	$200.00	807.61	$989.61	$789.61	100.14	13.39	4.9
Emergency Backup Lighting	$3.00	8.56	$10.48	$7.48	33.58	8.56	3.5
Handheld Barcode Scanners	$0.50	19.68	$19.86	$19.36	3.15	0.25	39.7
Two-Way Radios	$0.50	8.86	$8.94	$8.44	2.66	0.31	17.9
Single Phase Lift-Trucks	$200.00	1,032.64	$1,767.36	$1,567.36	30.77	2.41	9.5
Three Phase Lift Trucks	$400.00	4,198.51	$7,185.73	$6,785.73	316.57	24.52	18.0